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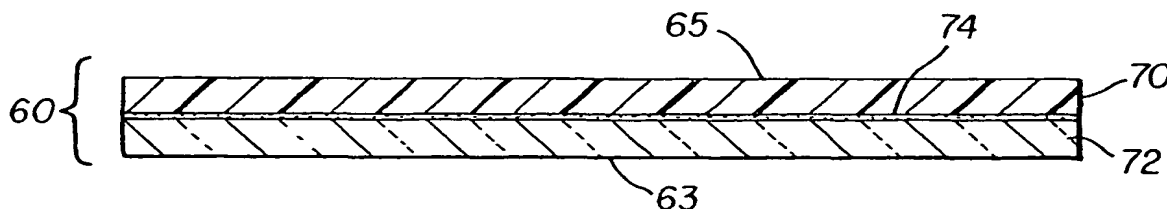
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(54) Title: **CORRECTING POTENTIAL DEFECTS IN AN OLED DEVICE**



(57) Abstract: A method of making an OLED device that corrects for potential defect(s) identified in one processing station by adjusting a subsequent processing station includes processing an OLED substrate by adding at least one organic layer and measuring in-situ one or more parameters associated with such organic layer to produce a signal representative of potential defect(s) in a produced OLED device, and adjusting in a subsequent processing station in response to the signal to change the formation of a subsequent organic layer added to the OLED device to compensate for the potential defect(s).

WO 2005/022661 A2

CORRECTING POTENTIAL DEFECTS IN AN OLED DEVICE

FIELD OF THE INVENTION

The present invention relates to making OLED devices which
5 includes using radiation thermal transfer, and for identifying potential defects and
correcting for such defects.

BACKGROUND OF THE INVENTION

Organic light-emitting diodes (OLEDs, also known as organic
light-emitting devices) are generally anticipated to overtake liquid crystal displays
10 (LCDs) as the preferred display technology. This is expected because OLEDs
enjoy a number of practical advantages over LCDs. Some of the most significant
advantages include: 1) OLEDs have a brighter image that can be viewed from
wider angles; 2) elimination of backlight required in LCDs lowers cost, increases
reliability, and improves image intensity range, contrast, and consistency over the
15 viewing area; 3) OLEDs require less power for equivalent image quality;
4) OLEDs are potentially cheaper to manufacture, requiring fewer materials and
roughly half the number of manufacturing steps; and 5) OLEDs produce a wider
spectrum of colors. However, OLED displays and their components known as
OLED structures, which constitute subpixels of the display, are more currently
20 difficult and costly to manufacture than LCD displays. It is a continuing focus of
the industry to increase throughput in an effort to lower the cost of OLED
manufacturing.

Conventional OLED display devices are built on glass substrates
such that a two-dimensional OLED array for image manifestation is formed. The
25 basic OLED cell structure includes of a stack of thin organic layers sandwiched
between an array of anodes and a common metallic cathode. The organic layers
commonly comprise a hole-transporting layer (HTL), a light-emitting layer (LEL),
and an electron-transporting layer (ETL). When an appropriate voltage is applied
to the cell, the injected holes and electrons recombine in the LEL near the

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LEL-HTL interface to produce light (electroluminescence).

The LEL within a color OLED display device most commonly includes three different types of fluorescent or phosphorescent molecules that are repeated through the LEL. Red, green, and blue regions, or subpixels, are formed throughout the LEL during the manufacturing process to provide a two-dimensional array of pixels. Each of the red, green, and blue subpixel sets undergoes a separate patterned deposition, typically by evaporating a linear source through a shadow mask. Shadow masking is a well known technology, yet it is limited in both the precision of its deposition pattern, and the pattern's fill factor or aperture ratio; thus, incorporating shadow masking into OLED manufacturing limits the achievable sharpness and resolution of the resultant display. Radiation thermal transfer (RTT) promises significant advantages including a more precise deposition pattern and higher aperture ratio; however, it has proved challenging to adapt RTT to a high-throughput manufacturing line.

During RTT, a donor sheet having the desired organic material is placed into close proximity to the OLED substrate in a vacuum chamber. A source of radiation, such as a laser, impinges upon the donor sheet through a clear support to the donor sheet and is absorbed within a light-absorbing layer contained atop the support. The conversion of the radiation energy to heat sublimates the organic material that forms the top layer of the donor sheet and thereby transfers the organic material in a sharply defined subpixel pattern to the OLED substrate.

The quality of the RTT process is dependent on several key process and product parameters. Real-time knowledge of how these process and product parameters vary during manufacturing is an important aspect in making the RTT process repeatable and cost effective. What is needed is a way to measure key process and product parameters in-situ.

U.S. Patent 6,485,884 provides a method for patterning oriented materials to make OLED display devices, and also provides donor sheets for use with the method, as well as methods for making the donor sheets. However, U.S.

Patent 6,485,884 patent fails to provide a system that enables in-situ monitoring of process and product parameters. To date, however, in-situ monitoring of process and product parameters has not been adapted to RTT.

SUMMARY OF THE INVENTION

5 It is therefore an object of the present invention to measure and analyze key process and product parameters in laser thermal transfer for improving the yield and quality of OLED devices.

It is another object of the invention to ensure that transfer of donor material in radiation thermal transfer processing has occurred and is of sufficient
10 quality to continue processing.

It is yet another object of the invention to provide a way to utilize in-situ measurement data to compensate and thus improve the yield and throughput of acceptable products through radiation thermal transfer.

This object is achieved by a method of making an OLED device
15 that corrects for potential defect(s) identified in one processing station by adjusting a subsequent processing station, comprising:

a) processing an OLED substrate by adding at least one organic layer and measuring in-situ one or more parameters associated with such organic layer to produce a signal representative of potential defect(s) in a produced
20 OLED device; and

b) adjusting in a subsequent processing station in response to the signal to change the formation of a subsequent organic layer added to the OLED device to compensate for the potential defect(s).

ADVANTAGES

25 It is an advantage of this invention that it permits less waste and additional throughput in the manufacture of OLED devices, thus increasing the efficiency of the manufacturing process. In-situ monitoring is important in determining whether a transfer of material has occurred and in ensuring the quality of the transfer. Further, in-situ monitoring eliminates any potential contamination
30 that can occur during ex-situ testing. In-situ process and product parameter

monitoring can enable compensations to be made in processes that occur downstream during the OLED manufacturing process, thereby improving yield and increasing throughput.

BRIEF DESCRIPTION OF THE DRAWINGS

5 FIG. 1 shows a cross-sectional view of a pixel of an OLED device which can be used according to a first embodiment of the present invention;

 FIG. 2 shows a cross-sectional representation of one embodiment of the structure of a donor that can be used in the method described herein;

 FIG. 3 is a cross-sectional view of one embodiment of the
10 placement of a donor against a substrate in accordance with this invention;

 FIG. 4 is a cross-sectional representation of one embodiment of an apparatus that can be used to effect the method of this invention;

 FIG. 5 illustrates a process flow in accordance with the present
15 invention for the in-situ characterization of process parameters for a radiation thermal transfer deposition process;

 FIG. 6 is a block diagram of one embodiment of a method of making an OLED device in accordance with this invention; and

 FIG. 7 is a block diagram of another embodiment of a method of making an OLED device in accordance with this invention.

20 Since device feature dimensions such as layer thicknesses are frequently in sub-micrometer ranges, the drawings are scaled for ease of visualization rather than dimensional accuracy.

DETAILED DESCRIPTION OF THE INVENTION

 The term “display” or “display panel” is employed to designate a
25 screen capable of electronically displaying video images or text. The term “pixel” is employed in its art-recognized usage to designate an area of a display panel that can be stimulated to emit light independently of other areas. The term “OLED device” is used in its art-recognized meaning of a display device comprising organic light-emitting diodes as pixels. A color OLED device emits light of at
30 least one color. The term “multicolor” is employed to describe a display panel that

is capable of emitting light of a different hue in different areas. In particular, it is employed to describe a display panel that is capable of displaying images of different colors. These areas are not necessarily contiguous. The term "full color" is employed to describe multicolor display panels that are capable of emitting in the red, green, and blue regions of the visible spectrum and displaying images in any hue or combination of hues. The red, green, and blue colors constitute the three primary colors from which all other colors can be generated by appropriately mixing these three primaries. The term "hue" refers to the intensity profile of light emission within the visible spectrum, with different hues exhibiting visually discernible differences in color. The pixel or subpixel is generally used to designate the smallest addressable unit in a display panel. For a monochrome display, there is no distinction between pixel or subpixel. The term "subpixel" is used in multicolor display panels and is employed to designate any portion of a pixel which can be independently addressable to emit a specific color. For example, a blue subpixel is that portion of a pixel which can be addressed to emit blue light. In a full-color display, a pixel generally comprises three primary-color subpixels, namely blue, green, and red. For the purposes of this invention, the terms "pixel" and "subpixel" will be used interchangeably. The term "pitch" is used to designate the distance separating two pixels or subpixels in a display panel. Thus, a subpixel pitch means the separation between two subpixels.

Turning now to FIG. 1, there is shown a cross-sectional view of a pixel of an OLED device 10 which can be used according to a first embodiment of the present invention. In some embodiments, the pixel of OLED device 10 can be a subpixel as defined above. The pixel includes a substrate 15, an anode 20 disposed over substrate 15, and a cathode 50 spaced from anode 20. An optional hole-injecting layer 25 is disposed over anode 20, and hole-transporting layer 30 is disposed over hole-injecting layer 25. A light-emitting layer 35 is disposed over the hole-transporting layer 30. An electron-transporting layer 40 can be disposed over light-emitting layer 35. These layers will be described in more detail.

Substrate 15 can be an organic solid, an inorganic solid, or a

combination of organic and inorganic solids that provides a surface for receiving organic material from a donor. Substrate 15 can be rigid or flexible and can be processed as separate individual pieces, such as sheets or wafers, or as a continuous roll. Typical substrate materials include glass, plastic, metal, ceramic, semiconductor, metal oxide, semiconductor oxide, semiconductor nitride, or combinations thereof. Substrate 15 can be a homogeneous mixture of materials, a composite of materials, or multiple layers of materials. Substrate 15 can be an OLED substrate, that is a substrate commonly used for preparing OLED devices, e.g. active-matrix low-temperature polysilicon TFT substrate. The substrate 15 can either be light transmissive or opaque, depending on the intended direction of light emission. The light transmissive property is desirable for viewing the EL emission through the substrate. Transparent glass or plastic are commonly employed in such cases. For applications where the EL emission is viewed through the top electrode, the transmissive characteristic of the bottom support is immaterial, and therefore can be light transmissive, light absorbing or light reflective. Substrates for use in this case include, but are not limited to, glass, plastic, semiconductor materials, ceramics, and circuit board materials, or any others commonly used in the formation of OLED devices, which can be either passive-matrix devices or active-matrix devices.

An electrode is formed over substrate 15 and is most commonly configured as an anode 20. When EL emission is viewed through the substrate 15, anode 20 should be transparent or substantially transparent to the emission of interest. Common transparent anode materials useful in this invention are indium-tin oxide and tin oxide, but other metal oxides can work including, but not limited to, aluminum- or indium-doped zinc oxide, magnesium-indium oxide, and nickel-tungsten oxide. In addition to these oxides, metal nitrides such as gallium nitride, metal selenides such as zinc selenide, and metal sulfides such as zinc sulfide, can be used as an anode material. For applications where EL emission is viewed through the top electrode, the transmissive characteristics of the anode material are immaterial and any conductive material can be used, transparent, opaque or

reflective. Example conductors for this application include, but are not limited to, gold, iridium, molybdenum, palladium, and platinum. The preferred anode materials, transmissive or otherwise, have a work function of 4.1 eV or greater.

Desired anode materials can be deposited by any suitable means such as

5 evaporation, sputtering, chemical vapor deposition, or electrochemical means.

Anode materials can be patterned using well known photolithographic processes.

While not always necessary, it is often useful that a hole-injecting layer **25** be formed over anode **20** in an organic light-emitting display. The hole-injecting material can serve to improve the film formation property of subsequent organic layers and to facilitate injection of holes into the hole-transporting layer.

10 Suitable materials for use in hole-injecting layer **25** include, but are not limited to, porphyrinic compounds as described in U.S. Patent 4,720,432, and plasma-deposited fluorocarbon polymers as described in U.S. Patent 6,208,075.

Alternative hole-injecting materials reportedly useful in organic EL devices are
15 described in EP 0 891 121 A1 and EP 1,029,909 A1.

While not always necessary, it is often useful that a hole-transporting layer **30** be formed over the hole-injecting layer **25**, or over anode **20** if no hole-injecting layer is used. Desired hole-transporting materials can be deposited by any suitable means such as evaporation, sputtering, chemical vapor
20 deposition, electrochemical means, thermal transfer, or laser thermal transfer from a donor material. Hole-transporting materials useful in hole-transporting layer **30** are well known to include compounds such as an aromatic tertiary amine, where the latter is understood to be a compound containing at least one trivalent nitrogen atom that is bonded only to carbon atoms, at least one of which is a member of an aromatic ring. In one form the aromatic tertiary amine can be an arylamine, such
25 as a monoarylamine, diarylamine, triarylamine, or a polymeric arylamine.

Exemplary monomeric triarylamine are illustrated by Klupfel et al. in U.S. Patent 3,180,730. Other suitable triarylamine substituted with one or more vinyl radicals and/or comprising at least one active hydrogen-containing group are disclosed by

30

Brantley et al. in U.S. Patents 3,567,450 and 3,658,520.

A more preferred class of aromatic tertiary amines are those which include at least two aromatic tertiary amine moieties as described in U.S. Patents 4,720,432 and 5,061,569. Such compounds include those represented by structural

5 Formula A.



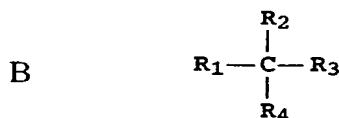
wherein:

Q₁ and Q₂ are independently selected aromatic tertiary amine moieties; and

G is a linking group such as an arylene, cycloalkylene, or alkylene group of a carbon to carbon bond.

- 10 In one embodiment, at least one of Q₁ or Q₂ contains a polycyclic fused ring structure, e.g., a naphthalene. When G is an aryl group, it is conveniently a phenylene, biphenylene, or naphthalene moiety.

A useful class of triarylamines satisfying structural Formula A and containing two triarylamine moieties is represented by structural Formula B.



15 where:

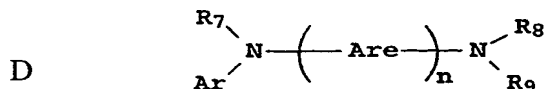
R₁ and R₂ each independently represent a hydrogen atom, an aryl group, or an alkyl group or R₁ and R₂ together represent the atoms completing a cycloalkyl group; and

- 20 R₃ and R₄ each independently represent an aryl group, which is in turn substituted with a diaryl substituted amino group, as indicated by structural Formula C.



wherein R₅ and R₆ are independently selected aryl groups. In one embodiment, at least one of R₅ or R₆ contains a polycyclic fused ring structure, e.g., a naphthalene.

Another class of aromatic tertiary amines are the tetraaryldiamines. Desirable tetraaryldiamines include two diarylamino groups, such as indicated by Formula C, linked through an arylene group. Useful tetraaryldiamines include those represented by Formula D.



5 wherein:

each Are is an independently selected arylene group, such as a phenylene or anthracene moiety;

n is an integer of from 1 to 4; and

Ar, R₇, R₈, and R₉ are independently selected aryl groups.

10 In a typical embodiment, at least one of Ar, R₇, R₈, and R₉ is a polycyclic fused ring structure, e.g., a naphthalene.

The various alkyl, alkylene, aryl, and arylene moieties of the foregoing structural Formulae A, B, C, D, can each in turn be substituted. Typical substituents include alkyl groups, alkoxy groups, aryl groups, aryloxy groups, and
15 halogens such as fluoride, chloride, and bromide. The various alkyl and alkylene moieties typically contain from 1 to about 6 carbon atoms. The cycloalkyl moieties can contain from 3 to about 10 carbon atoms, but typically contain five, six, or seven carbon atoms--e.g., cyclopentyl, cyclohexyl, and cycloheptyl ring structures. The aryl and arylene moieties are usually phenyl and phenylene moieties.

20 The hole-transporting layer in an OLED device can be formed of a single or a mixture of aromatic tertiary amine compounds. Specifically, one can employ a triarylamine, such as a triarylamine satisfying the Formula B, in combination with a tetraaryldiamine, such as indicated by Formula D. When a triarylamine is employed in combination with a tetraaryldiamine, the latter is
25 positioned as a layer interposed between the triarylamine and the electron-injecting and transporting layer. Illustrative of useful aromatic tertiary amines are the following:

1,1-Bis(4-di-*p*-tolylaminophenyl)cyclohexane

1,1-Bis(4-di-*p*-tolylaminophenyl)-4-phenylcyclohexane

- 4,4'-Bis(diphenylamino)quadriphenyl
Bis(4-dimethylamino-2-methylphenyl)-phenylmethane
N,N,N-Tri(*p*-tolyl)amine
4-(di-*p*-tolylamino)-4'-[4(di-*p*-tolylamino)-styryl]stilbene
5 N,N,N',N'-Tetra-*p*-tolyl-4,4'-diaminobiphenyl
N,N,N',N'-Tetraphenyl-4,4'-diaminobiphenyl
N-Phenylcarbazole
Poly(N-vinylcarbazole)
N,N'-di-1-naphthalenyl-N,N'-diphenyl-4,4'-diaminobiphenyl
10 4,4'-Bis[N-(1-naphthyl)-N-phenylamino]biphenyl
4,4''-Bis[N-(1-naphthyl)-N-phenylamino]*p*-terphenyl
4,4'-Bis[N-(2-naphthyl)-N-phenylamino]biphenyl
4,4'-Bis[N-(3-acenaphthenyl)-N-phenylamino]biphenyl
1,5-Bis[N-(1-naphthyl)-N-phenylamino]naphthalene
15 4,4'-Bis[N-(9-anthryl)-N-phenylamino]biphenyl
4,4''-Bis[N-(1-anthryl)-N-phenylamino]-*p*-terphenyl
4,4'-Bis[N-(2-phenanthryl)-N-phenylamino]biphenyl
4,4'-Bis[N-(8-fluoranthenyl)-N-phenylamino]biphenyl
4,4'-Bis[N-(2-pyrenyl)-N-phenylamino]biphenyl
20 4,4'-Bis[N-(2-naphthacenyl)-N-phenylamino]biphenyl
4,4'-Bis[N-(2-perylenyl)-N-phenylamino]biphenyl
4,4'-Bis[N-(1-coronenyl)-N-phenylamino]biphenyl
2,6-Bis(di-*p*-tolylamino)naphthalene
2,6-Bis[di-(1-naphthyl)amino]naphthalene
25 2,6-Bis[N-(1-naphthyl)-N-(2-naphthyl)amino]naphthalene
N,N,N',N'-Tetra(2-naphthyl)-4,4''-diamino-*p*-terphenyl
4,4'-Bis{N-phenyl-N-[4-(1-naphthyl)-phenyl]amino}biphenyl
4,4'-Bis[N-phenyl-N-(2-pyrenyl)amino]biphenyl
2,6-Bis[N,N-di(2-naphthyl)amine]fluorene
30 1,5-Bis[N-(1-naphthyl)-N-phenylamino]naphthalene

Another class of useful hole-transporting materials includes polycyclic aromatic compounds as described in EP 1 009 041. In addition, polymeric hole-transporting materials can be used such as poly(N-vinylcarbazole) (PVK), polythiophenes, polypyrrole, polyaniline, and copolymers such as poly(3,4-ethylenedioxythiophene)/poly(4-styrenesulfonate) also called PEDOT/PSS.

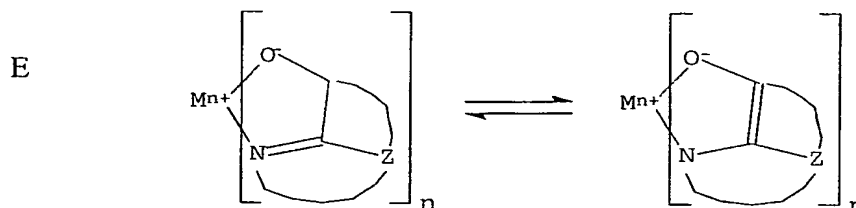
Light-emitting layer 35 produces light in response to hole-electron recombination. Light-emitting layer 35 is formed over anode 20 and over any other layers formed, such as hole-transporting layer 30. Desired organic light-emitting materials can be deposited by any suitable means such as evaporation, sputtering, chemical vapor deposition, electrochemical means, or radiation thermal transfer from a donor material. Useful organic light-emitting materials are well known. As more fully described in U.S. Patents 4,769,292 and 5,935,721, the light-emitting layers of the organic EL element comprise a luminescent or fluorescent material where electroluminescence is produced as a result of electron-hole pair recombination in this region. The light-emitting layers can be comprised of a single material, but more commonly include a host material doped with a guest compound or dopant where light emission comes primarily from the dopant and can be of any color. The host materials in the light-emitting layers can be an electron-transporting material, as defined below, a hole-transporting material, as defined above, or another material that supports hole-electron recombination. The dopant is usually chosen from highly fluorescent dyes, but phosphorescent compounds, e.g., transition metal complexes as described in WO 98/55561, WO 00/18851, WO 00/57676, and WO 00/70655 are also useful. Dopants are typically coated as 0.01 to 10% by weight into the host material.

An important relationship for choosing a dye as a dopant is a comparison of the bandgap potential which is defined as the energy difference between the highest occupied molecular orbital and the lowest unoccupied molecular orbital of the molecule. For efficient energy transfer from the host

material to the dopant molecule, a necessary condition is that the band gap of the dopant is smaller than that of the host material.

Host and emitting molecules known to be of use include, but are not limited to, those disclosed in U.S. Patents 4,768,292; 5,141,671; 5,150,006;
 5 5,151,629; 5,294,870; 5,405,709; 5,484,922; 5,593,788; 5,645,948; 5,683,823;
 5,755,999; 5,928,802; 5,935,720; 5,935,721; and 6,020,078.

Metal complexes of 8-hydroxyquinoline and similar derivatives (Formula E) constitute one class of useful host materials capable of supporting electroluminescence, and are particularly suitable for light emission of
 10 wavelengths longer than 500 nm, e.g., green, yellow, orange, and red.



wherein:

M represents a metal;

n is an integer of from 1 to 3; and

Z independently in each occurrence represents the atoms completing a
 15 nucleus having at least two fused aromatic rings.

From the foregoing it is apparent that the metal can be a monovalent, divalent, or trivalent metal. The metal can, for example, be an alkali metal, such as lithium, sodium, or potassium; an alkaline earth metal, such as magnesium or calcium; or an earth metal, such as boron or aluminum. Generally
 20 any monovalent, divalent, or trivalent metal known to be a useful chelating metal can be employed.

Z completes a heterocyclic nucleus containing at least two fused aromatic rings, at least one of which is an azole or azine ring. Additional rings, including both aliphatic and aromatic rings, can be fused with the two required
 25 rings, if required. To avoid adding molecular bulk without improving on function the number of ring atoms is usually maintained at 18 or less.

Illustrative of useful chelated oxinoid compounds are the following:

CO-1: Aluminum trisoxine [alias, tris(8-quinolinolato)aluminum(III)]

5 CO-2: Magnesium bisoxine [alias, bis(8-quinolinolato)magnesium(II)]

CO-3: Bis[benzo{f}-8-quinolinolato]zinc (II)

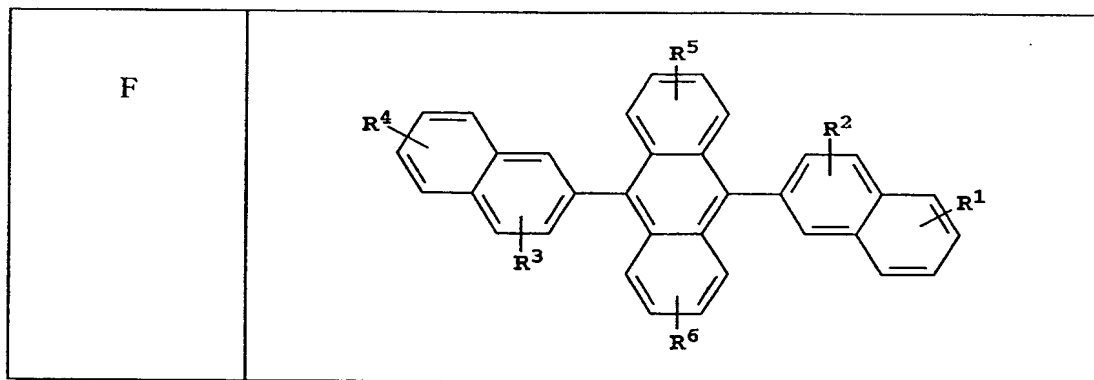
CO-4: Bis(2-methyl-8-quinolinolato)aluminum(III)- μ -oxo-bis(2-methyl-8-quinolinolato) aluminum(III)

CO-5: Indium trisoxine [alias, tris(8-quinolinolato)indium]

10 CO-6: Aluminum tris(5-methyloxine) [alias, tris(5-methyl-8-quinolinolato)aluminum(III)]

CO-7: Lithium oxine [alias, (8-quinolinolato)lithium(I)]

Derivatives of 9,10-di-(2-naphthyl)anthracene (Formula F) constitute one class of useful host materials capable of supporting
15 electroluminescence, and are particularly suitable for light emission of wavelengths longer than 400 nm, e.g., blue, green, yellow, orange or red.



wherein R^1 , R^2 , R^3 , R^4 , R^5 , and R^6 represent one or more substituents on each ring where each substituent is individually selected from the following groups:

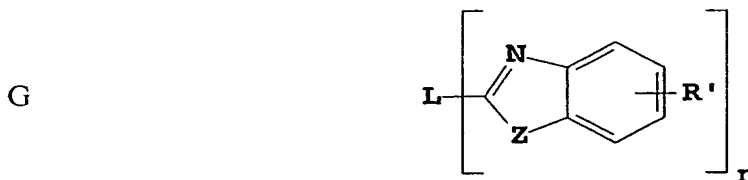
- 20 Group 1: hydrogen, or alkyl of from 1 to 24 carbon atoms;
 Group 2: aryl or substituted aryl of from 5 to 20 carbon atoms;
 Group 3: carbon atoms from 4 to 24 necessary to complete a fused aromatic ring of anthracenyl, pyrenyl, or perylenyl;

Group 4: heteroaryl or substituted heteroaryl of from 5 to 24 carbon atoms as necessary to complete a fused heteroaromatic ring of furyl, thienyl, pyridyl, quinolinyl or other heterocyclic systems;

Group 5: alkoxyamino, alkylamino, or arylamino of from 1 to 24 carbon atoms; and

Group 6: fluorine, chlorine, bromine or cyano.

Benzazole derivatives (Formula G) constitute another class of useful host materials capable of supporting electroluminescence, and are particularly suitable for light emission of wavelengths longer than 400 nm, e.g., blue, green, yellow, orange or red.



where:

n is an integer of 3 to 8;

Z is O, NR or S;

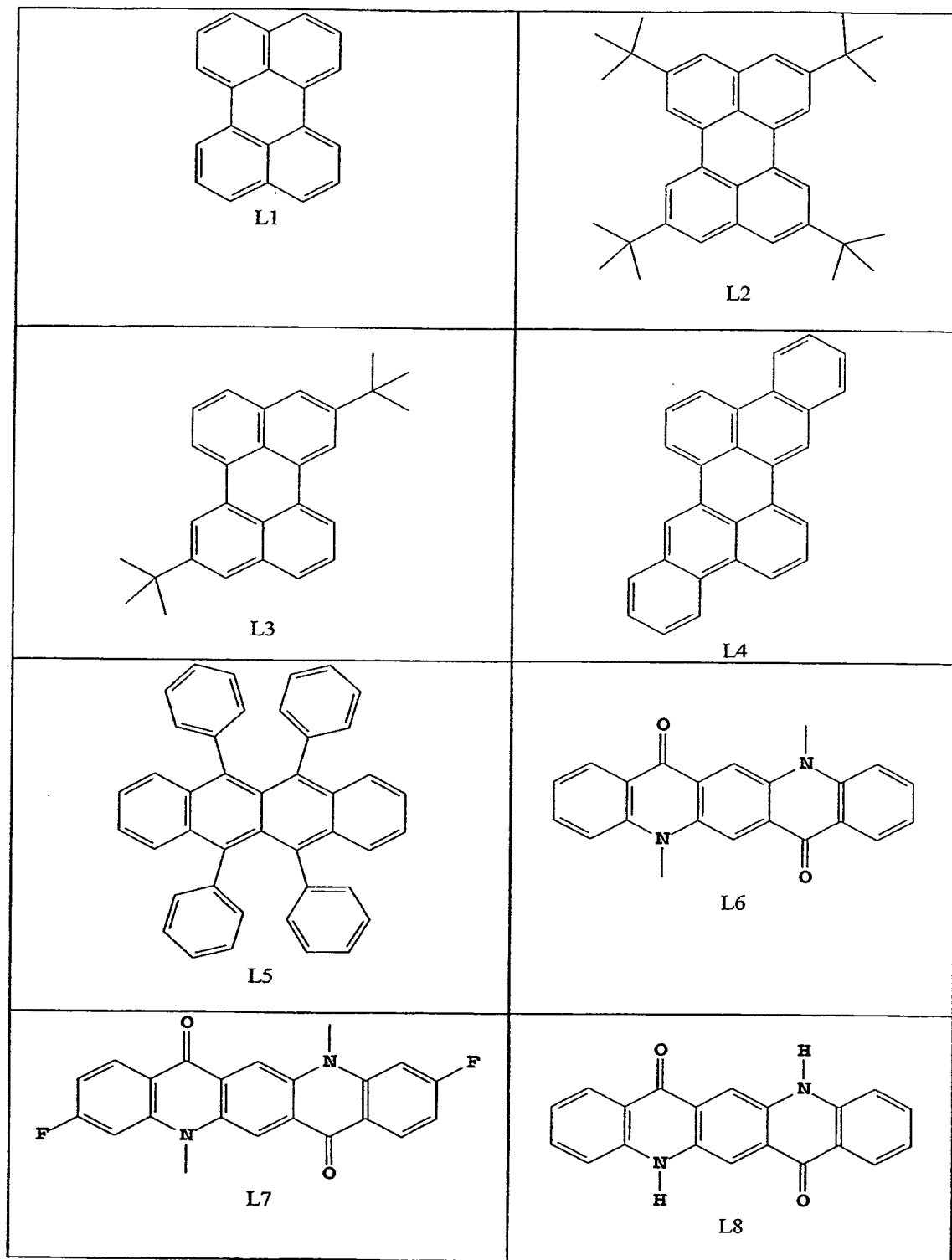
R' is hydrogen; alkyl of from 1 to 24 carbon atoms, for example, propyl, t-butyl, heptyl, and the like; aryl or heteroatom substituted aryl of from 5 to 20 carbon atoms for example phenyl and naphthyl, furyl, thienyl, pyridyl, quinolinyl and other heterocyclic systems; or halo such as chloro, fluoro; or atoms necessary to complete a fused aromatic ring; and

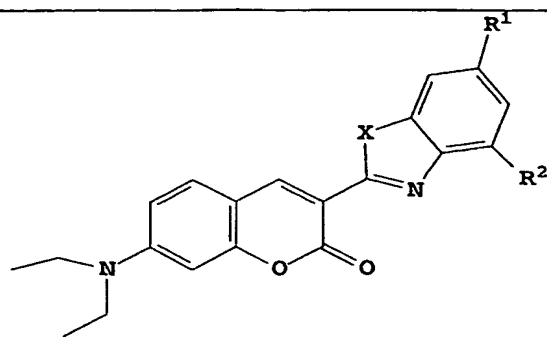
L is a linkage unit including alkyl, aryl, substituted alkyl, or substituted aryl, which conjugately or unconjugately connects the multiple benzazoles together.

An example of a useful benzazole is 2, 2', 2''-(1,3,5-phenylene)tris[1-phenyl-1H-benzimidazole].

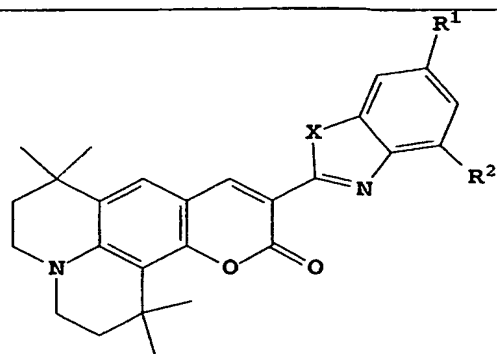
Desirable fluorescent dopants include derivatives of anthracene, tetracene, xanthene, perylene, rubrene, coumarin, rhodamine, quinacridone, dicyanomethylenepyran compounds, thiopyran compounds, polymethine compounds, pyrilium and thiapyrilium compounds, and carbostyryl compounds.

Illustrative examples of useful dopants include, but are not limited to, the following:

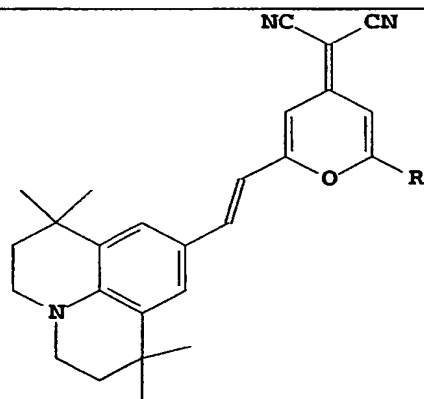




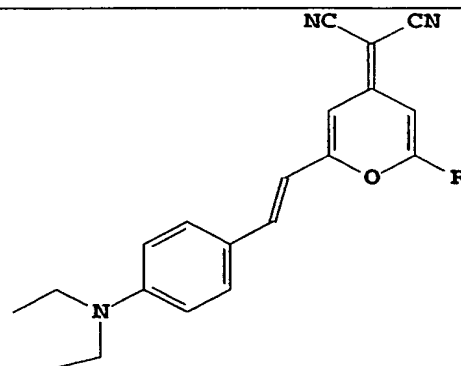
	<u>X</u>	<u>R1</u>	<u>R2</u>
L9	O	H	H
L10	O	H	Methyl
L11	O	Methyl	H
L12	O	Methyl	Methyl
L13	O	H	t-butyl
L14	O	t-butyl	H
L15	O	t-butyl	t-butyl
L16	S	H	H
L17	S	H	Methyl
L18	S	Methyl	H
L19	S	Methyl	Methyl
L20	S	H	t-butyl
L21	S	t-butyl	H
L22	S	t-butyl	t-butyl



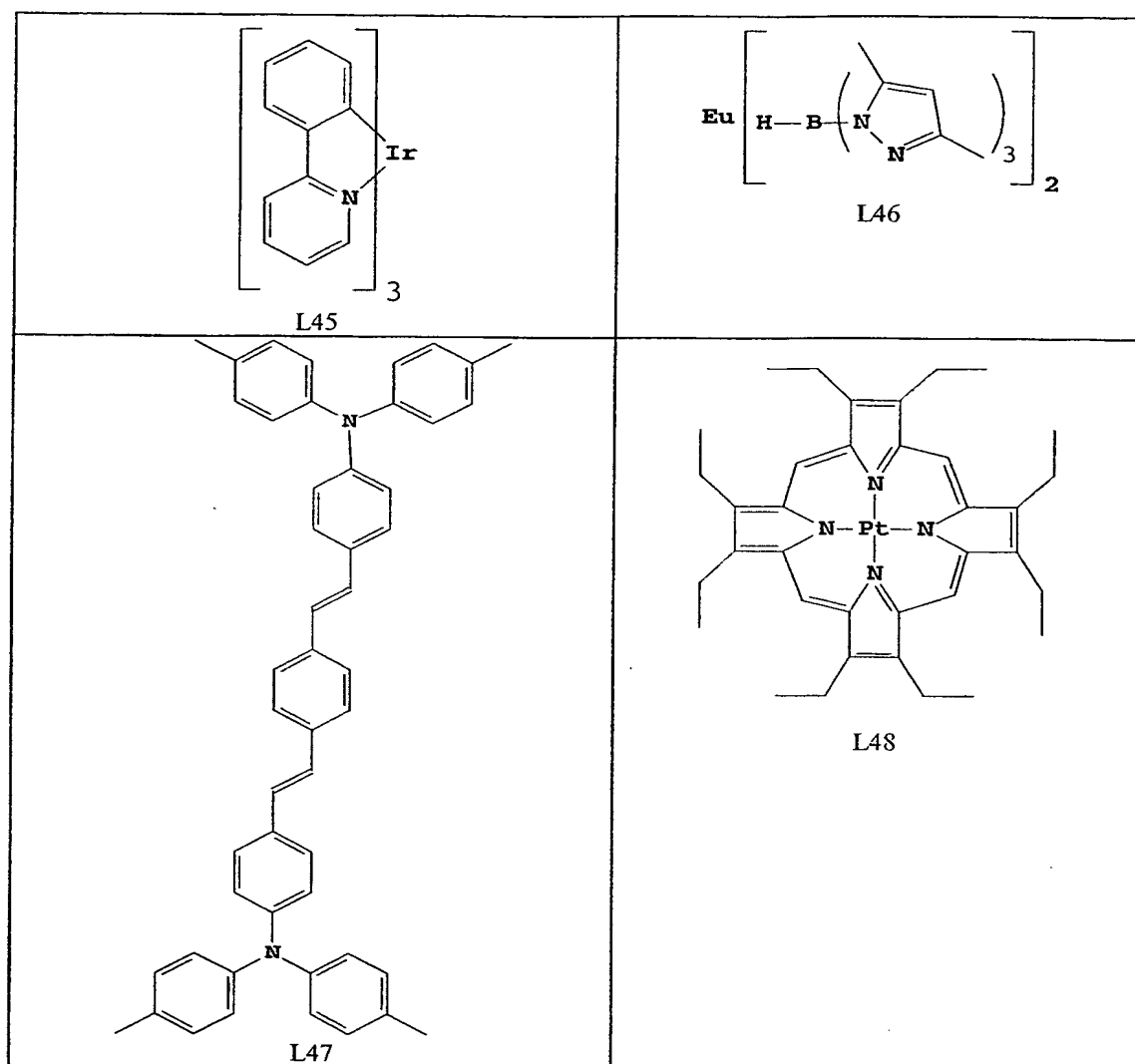
	<u>X</u>	<u>R1</u>	<u>R2</u>
L23	O	H	H
L24	O	H	Methyl
L25	O	Methyl	H
L26	O	Methyl	Methyl
L27	O	H	t-butyl
L28	O	t-butyl	H
L29	O	t-butyl	t-butyl
L30	S	H	H
L31	S	H	Methyl
L32	S	Methyl	H
L33	S	Methyl	Methyl
L34	S	H	t-butyl
L35	S	t-butyl	H
L36	S	t-butyl	t-butyl



	<u>R</u>
L37	phenyl
L38	methyl
L39	t-butyl
L40	mesityl



	<u>R</u>
L41	phenyl
L42	methyl
L43	t-butyl
L44	mesityl



Other organic emissive materials can be polymeric substances, e.g. polyphenylenevinylene derivatives, dialkoxy-polyphenylenevinylenes, poly-para-phenylene derivatives, and polyfluorene derivatives, as taught by Wolk et al. in
 5 commonly assigned U.S. Patent 6,194,119 B1 and references cited therein.

Although not shown, the device can additionally comprise more than two emissive layers, if such is desired for proper emissive properties of the resulting OLED device.

10 While not always necessary, it is often useful that an electron-transporting layer 40 be formed over light-emitting layer 35. Desired electron-transporting materials can be deposited by any suitable means such as evaporation,

sputtering, chemical vapor deposition, electrochemical means, thermal transfer, or laser thermal transfer from a donor material. Preferred electron-transporting materials for use in electron-transporting layer 40 are metal chelated oxinoid compounds, including chelates of oxine itself (also commonly referred to as 8-quinolinol or 8-hydroxyquinoline). Such compounds help to inject and transport electrons and exhibit both high levels of performance and are readily fabricated in the form of thin films. Exemplary of contemplated oxinoid compounds are those satisfying structural Formula E, previously described.

Other electron-transporting materials include various butadiene derivatives as disclosed in U.S. Patent 4,356,429 and various heterocyclic optical brighteners as described in U.S. Patent 4,539,507. Benzazoles satisfying structural Formula G are also useful electron-transporting materials.

Other electron-transporting materials can be polymeric substances, e.g. polyphenylenevinylene derivatives, poly-para-phenylene derivatives, polyfluorene derivatives, polythiophenes, polyacetylenes, and other conductive polymeric organic materials such as those listed in *Handbook of Conductive Molecules and Polymers*, Vols. 1-4, H.S. Nalwa, ed., John Wiley and Sons, Chichester (1997).

It will be understood that, as is common in the art, some of the layers described above can have more than one function. For example, light-emitting layer 35 can have hole-transporting properties or electron-transporting properties as desired for performance of the OLED device. Hole-transporting layer 30 or electron-transporting layer 40, or both, can have emitting properties. In such a case, fewer layers can be sufficient for the desired emissive properties.

Cathode 50 is formed over the electron-transporting layer 40 or over light-emitting layers 35 if an electron-transporting layer is not used. When light emission is through the anode 20, the cathode material can be comprised of nearly any conductive material. Desirable materials have good film-forming properties to ensure good contact with the underlying organic layer, promote electron injection at low voltage, and have good stability. Useful cathode materials often contain a low work function metal (< 3.0 eV) or metal alloy. One preferred

cathode material is comprised of a Mg:Ag alloy wherein the percentage of silver is in the range of 1 to 20%, as described in U.S. Patent 4,885,221. Another suitable class of cathode materials includes bilayers comprised of a thin layer of a low work function metal or metal salt capped with a thicker layer of conductive metal.

- 5 One such cathode is comprised of a thin layer of LiF followed by a thicker layer of Al as described in U.S. Patent 5,677,572. Other useful cathode materials include, but are not limited to, those disclosed in U.S. Patents 5,059,861; 5,059,862; and 6,140,763.

When light emission is viewed through the cathode, the cathode
10 must be transparent or nearly transparent. For such applications, metals must be thin or one must use transparent conductive oxides, or a combination of these materials. Optically transparent cathodes have been described in more detail in U.S. Patent 5,776,623. Cathode materials can be deposited by evaporation, sputtering, or chemical vapor deposition. When needed, patterning can be
15 achieved through many well known methods including, but not limited to, through-mask deposition, integral shadow masking as described in U.S. Patent 5,276,380 and EP 0 732 868, laser ablation, and selective chemical vapor deposition.

Cathode 50 is an electrode vertically spaced apart from anode 20.
20 Cathode 50 can be part of an active matrix device and in that case is a single electrode for the entire display. Alternatively, cathode 50 can be part of a passive matrix device, in which each cathode 50 can activate a column of pixels, and cathodes 50 are arranged orthogonal to anodes 20.

An electron-injecting layer can also be present between the cathode
25 and the electron-transporting layer. Examples of electron-injecting materials include alkali halide salts, such as LiF mentioned above.

Turning now to FIG. 2, there is shown a cross-sectional representation of one embodiment of the structure of a donor 60 that can be used in the method and apparatus described herein. Donor 60 can be formed in a sheet or as a continuous roll. Donor 60 includes at the minimum a support 72 that is
30 preferably flexible, which comprises non-transfer surface 63. Support 72 is first

uniformly coated with radiation-absorbing layer 74 that includes a radiation-absorbing material capable of absorbing radiation in a predetermined portion of the spectrum to produce heat so as to cause the transfer of organic material, then coated with a layer of heat-transferable organic material 70. Support 72 then
5 comprises non-transfer surface 63 of donor 60 and organic material 70 comprises transfer surface 65 of donor 60. Radiation-absorbing layer 74 is capable of absorbing radiation in a predetermined portion of the spectrum thereby producing heat. The radiation-absorbing material can be a dye such as the dyes specified in U.S. Patent 5,578,416, a pigment such as carbon, or a metal such as nickel,
10 chromium, titanium, etc.

Support 72 can be made of any of several materials which meet at least the following requirements. It must be capable of maintaining its structural integrity during the organic material transfer step while it is pressurized on one side, and during any pre-treat heating steps contemplated to remove volatile
15 constituents such as water vapor. Additionally, support 72 must be capable of receiving on one surface a relatively thin coating of organic material 70, and of retaining this coating without degradation during anticipated storage periods of the coated support (donor 60). Support materials meeting these requirements include, for example, metal foils, certain plastic foils which exhibit a glass transition
20 temperature value higher than a support temperature value anticipated to cause transfer of the transferable organic material 70 coated on support 72, and fiber-reinforced plastic foils. While selection of suitable support materials can rely on known engineering approaches, it will be appreciated that certain aspects of a selected support material merit further consideration when configured as a donor
25 support useful in the practice of the invention. For example, support 72 can require a multi-step cleaning and surface preparation process prior to precoating with radiation-absorbing layer 74 or organic material 70.

FIG. 3 shows a cross-section view of one embodiment of the placement of donor 60 against substrate 15 in accordance with this invention. In
30 this embodiment, receiving surface 86 of substrate 15 is uneven due to the presence of thin-film transistors 80. Thin-film transistors 80 are separated in

substrate 15 by raised surface portions 82 as a result of the multilayer construction of each pixel or subpixel. This is described by Tang in commonly assigned U.S. Patent 5,937,272, the disclosure of which is incorporated herein by reference. The presence of raised surface portions 82 maintains the separation of gap 84 against
5 the pressure that is exerted by the pressurizing fluid against non-transfer surface 63 and maintains a separation between portions of donor 60 and substrate 15.

FIG. 3 also shows the process of using radiation to transfer organic material 70 from donor 60 to portions of substrate 15. A pattern of radiation such as laser light beam 62 irradiates non-transfer surface 63. Heat 90 is produced when
10 laser light beam 62 strikes radiation-absorbing layer 74, permitting heat 90 to be absorbed by organic material 70 in the immediate vicinity of laser light beam 62, which causes the transfer of organic material 70 to substrate 15. A large portion of the light impinging on donor 60 will be converted to heat, but this will only happen at selectively irradiated portions of donor 60. Some or all of the heated
15 portion of organic material 70 undergoes organic material transfer, that is, it is sublimed, vaporized, or ablated and becomes organic layer 92 on receiving surface 86 of substrate 15 in a patterned transfer.

Defects are possible during this process. For example, a portion of organic material 70 can be missing or of a reduced thickness, thus being a defect
20 in donor 60. Such a defective portion of donor 60 can lead to a defect in organic layer 92 upon the radiation thermal transfer process. Also, an inefficient radiation thermal transfer process can lead to incomplete organic material transfer and a defect in organic layer 92 on OLED substrate 15. For example, the thickness of organic layer 92 can be insufficient for proper electroluminescence. Such a defect
25 in organic layer 92 will also be referred to herein as a potential defect in the produced OLED device.

Turning now to FIG. 4, we see a cross-sectional representation of one embodiment of an apparatus that can be used to effect the method of this invention in which an OLED substrate 15 is coated in three processing stations in
30 the same controlled environment coater 100. Controlled environment coater 100 is an enclosed apparatus described herein that permits an in-situ method for

fabricating an OLED device under controlled-environment conditions and includes unitary housing **110** which encompasses three coating stations, at least one of which is a radiation thermal transfer station, a measurement station, and one or more robots. By controlled environment, we mean that the water vapor partial pressure is preferably 1 Torr or less, or the oxygen partial pressure is preferably 1 Torr or less, or both. This can be accomplished by maintaining a vacuum inside the controlled environment coater **100**. This can also be accomplished by maintaining a water vapor level of preferably 1000 ppm or less, or an oxygen level of preferably 1000 ppm or less, or both, at a total pressure greater than 1 Torr inside controlled environment coater **100**. While controlled environment coater **100** is shown as a single chamber, it can also include two or more chambers in which at least one chamber is maintained under a vacuum, and at least one chamber is maintained under a higher-pressure controlled environment as described above. Such an apparatus has been described previously in commonly assigned U.S. Patent Application Serial No. 10/141,587 filed May 8, 2002 by Michael L. Boroson et al., entitled "In-Situ Method for Making OLED Devices That Are Moisture or Oxygen-Sensitive", the disclosure of which is herein incorporated by reference. While it is impossible to reduce the quantities of water vapor and/or oxygen completely to zero, controlled environment conditions can reduce the quantities of these components to very low or imperceptible levels, such as 0.001 ppm. Controlling the environment can be achieved by various well known methods, e.g. oxygen or water-vapor scrubbers, or the use of purified gasses. Controlled environment coater **100** can include one chamber, or any number of chambers that can be connected by load locks or similarly-acting apparatus such as tunnels or buffer chambers, whereby donor elements and receiver elements can be transported without exposure to moisture and/or oxygen. The conditions are maintained in controlled environment coater **100** by a means for controlling the atmosphere, e.g. controlled environment source **112**. Controlled environment coater **100** can include load lock **114**, which is used to load substrates **15**, and load lock **116**, which is used to unload completed OLED devices. Several embodiments of controlled environment coater **100** have been more fully

described in commonly assigned U.S. Patent Application Serial No. 10/141,587 filed May 8, 2002 by Michael L. Boroson et al., entitled "In-Situ Method for Making OLED Devices That Are Moisture or Oxygen-Sensitive", the disclosure of which is herein incorporated by reference.

5 The interior of this embodiment of controlled environment coater 100 can include coating station 120, robots 122 and 128, radiation thermal transfer station 124, measurement station 126, and coating station 130. Coating station 120, radiation thermal transfer station 124, and coating station 130 are processing stations. In this embodiment, the stations are sequentially positioned in line, so
10 that a substrate 15 can be sequentially moved in line through the different stations. Coating station 120 is a means for coating one or more organic layers over a substrate 15 e.g. a structure for applying a hole-transporting material over the substrate 15 by e.g. vapor deposition or other substantially uniform means. Coating means or coating apparatus 134 can represent e.g. a heated boat, a point
15 vapor source, etc. It will be understood that other coating methods are possible, e.g. solvent coating, and that the relative positions of substrate 15 above or below coating apparatus 134 will depend on the type of coating. Coating station 120 can coat one or more organic layers on substrate 15. For example, the use of two or more coating apparatus 134, movable in relation to substrate 15, will permit
20 multiple organic layers to be coated.

Controlled environment coater 100 also includes a robot 122. Robot 122 is an actuable robot control means for grasping and removing substrate 15 from coating station 120 after substrate 15 has been coated, and positioning coated substrate 15 into radiation thermal transfer station 124 so that it is in a
25 material transferring relationship with donor 60. For the purposes of this discussion, a robot shall include the apparatus necessary to move a web in the case where substrate 15 is in the form of a continuous web or roll. Robot 122 can include a grasping means 131 by which it can grasp and remove substrate 15 from coating station 120 and position the coated substrate 15 in radiation thermal
30 transfer station 124.

Radiation thermal transfer station **124** is a processing station that processes OLED substrate **15** by adding at least one organic layer by a radiation thermal transfer process. It can hold substrate **15** in a material transferring relationship with donor **60**, which includes light-emitting organic material.

- 5 Radiation thermal transfer station **124** can be e.g. an apparatus such as that described in commonly assigned U.S. Patent Application Serial No. 10/021,410 filed December 12, 2001 by Bradley A. Phillips et al., entitled "Apparatus for Permitting Transfer of Organic Material From a Donor to Form a Layer in an OLED Device", the disclosures of which are herein incorporated by reference.
- 10 Radiation thermal transfer station **124** is shown for convenience in the closed configuration, but it also has an open configuration in which the donor **60** and substrate **15** loading and unloading occurs. By material transferring relationship we mean the coated side of donor **60** is positioned in close contact with the receiving surface of substrate **15** and held in place by a means such as fluid
- 15 pressure in a pressure chamber, as described by Phillips, et al. Radiation thermal transfer station **124** is constructed so as to facilitate forming an emissive layer on substrate **15** through the selective transfer of organic material from donor **60** to substrate **15** by applying radiation from an actuable radiation means, e.g. laser light beam **62** from laser **138**, through transparent portion **146**. Radiation thermal
- 20 transfer is herein defined as any mechanism such as sublimation, ablation, vaporization or other process whereby material can be transferred upon initiation by radiation. The irradiation of donor **60** in a predetermined pattern selectively transfers one or more layers of coated material from donor **60** to substrate **15** so that material will coat selected portions of substrate **15**, as described by Phillips et
- 25 al.

Controlled environment coater **100** also includes measurement station **126**, which includes measurement apparatus **140**. Measurement apparatus **140** is an apparatus capable of measuring in-situ one or more parameters (e.g. thickness) associated with an organic layer such as light-emitting layer **35** coated

30 on OLED substrate **15** to produce a signal representative of potential defects in OLED device **10**. Measurement apparatus **140** can thereby identify potential

defects in one processing station (e.g. radiation thermal transfer station **124**) and produce a signal representative of the potential defects. Such a measurement apparatus **140** can be e.g. in-situ spectroscopic ellipsometry, which is commercially available from J.A. Woolam Co., Inc., and others. Other methods of measurement are also possible, and can include destructive tests that are performed on test sites that will not be utilized in the final OLED display device (e.g. near the edge of a panel), or non-destructive tests that can be performed anywhere on OLED substrate **15**. Destructive in-situ tests that can be performed on test sites can include photoluminescence to check the quality of the transferred material layer, Kelvin probe testing to measure the work function of the transferred material layer, atomic force microscopy (AFM) tests to determine the thickness and resolution of the transferred material layer, laser desorption mass spectroscopy to determine impurities, micro-Raman spectroscopy, X-ray fluorescence, or four point probe measurements. Nondestructive in-situ tests can include diffracting a laser beam off of a set of lines that form a grating, or ellipsometry on the transferred material to ascertain transfer layer thickness and density.

Controlled environment coater **100** also includes coating station **130**, which is a means for forming an electron-transporting layer over the first and second organic layers of emissive coated substrate **15** that had been previously coated in coating station **120** and radiation thermal transfer station **124**. Coating apparatus **148** can represent e.g. one or more heated boats for vaporizing materials to form the desired layer.

These operations can be simultaneous at the various stations. For example, a substrate **15** can undergo radiation thermal transfer at radiation thermal transfer station **124**, while a previously-transferred substrate **15** is being coated at coating station **130**, another previously-transferred substrate **15** is being measured at measurement station **126**, and an uncoated substrate **15** is being coated at coating station **120**.

A process control means, e.g. computer **150** can be arranged to control this process via data input/outputs **152**, **154**, **156**, and **158**. Robots **122** and

128 can be controlled by computer 150 via data input/outputs 152 and 158, respectively. Of particular importance to this method is that computer 150 controls measurement apparatus 140, and receives a signal representative of potential defects in coated substrate 15, via data input/output 154. Computer 150 can then
5 adjust one or more subsequent steps or one or more subsequent processing stations in response to the signal to change the formation of a subsequent organic layer added to OLED substrate 15 to compensate for potential defects. For example, if a defect is detected in substrate 15 by measurement apparatus 140, computer 150 can adjust the subsequent processing station, that is coating station 130, in
10 response to the defect signal, thereby changing the formation of the subsequent organic layer (e.g. the electron-transporting layer 40) added to OLED substrate 15 at coating station 130. For example, if the signal from measurement apparatus 140 indicates an undesired thickness of the OLED layer(s), computer 150 can adjust the thickness of the subsequent organic layer deposited at coating station 130.
15 Such adjustment can be effected by e.g. changing the rate of vaporization from coating apparatus 148, or by changing the residence time of OLED substrate 15 in coating station 130.

Alternatively, computer 150 can control robot 128 to reject the device if there is a defect, e.g. if insufficient organic material was transferred, so
20 that OLED substrate 15 is not passed to coating station 130, but is removed from the system. Alternatively, computer 150 can control robot 128 to transfer the rejected device to a reworking station that can rework rejected OLED substrate 15 to correct for identified defects, e.g. to correct for insufficient organic material transfer. A reworking station can be an additional station, or can be radiation
25 thermal transfer station 124 to which substrate 15 can be returned for reworking to correct for identified defects, such reworking can include radiation thermal transfer of an organic layer to the defective locations of substrate 15 using an additional donor 60.

Although not shown, computer 150 can also be a process control
30 means for controlling in a time sequence the actuation of the coating means, that is

stations **120**, **124**, and **130**, respectively. Computer **150** can also control the actuatable radiation means, that is laser **138**.

Although FIG. 4 shows a system comprising three coating stations and one measurement station in a particular order, those skilled in the art will understand that this invention is not limited to this arrangement. For example, a measurement station can be located before radiation thermal transfer station **124** for testing donor **60**. Such an arrangement would permit a donor **60** with defects or defective portions to be rejected before it is used to produce an unacceptable OLED device from OLED substrate **15**. Alternatively, the identified defective portions of donor **60** can be excluded in the process to form an organic layer on OLED substrate **15**, thus transferring organic material **70** only from acceptable portions of donor **60** and reducing waste for OLED substrates **15**. This is a particularly effective method if donor **60** is in the form of a continuous web, but can also be used if donor **60** is in the form of sheets. Particularly effective methods for testing donor **60** in this invention include in-situ spectroscopic ellipsometry, automated image analysis, and automated absorption and transmission measurements.

FIG. 5 illustrates a process flow **200** in accordance with the present invention for the in-situ characterization of process parameters for a radiation thermal transfer deposition process. Process flow **200** includes a donor support **72** that can be a continuous roll of extruded web that is, in one example, 3 mils thick, 22 inches wide, and hundreds of yards long; alternately, donor support **72** can be a plurality of precut and framed donor sheets. Although donor support **72** has been quality control-tested prior to being supplied to process flow **200**, additional testing can be desirable in order to ascertain moisture content, contamination, deformities such as pinholes or non-uniform areas in the chromium light-absorbing layer, the thicknesses of the light-absorbing and antireflecting layers, etc. Therefore, donor support **72** can be subjected to one or more uncoated donor support tests **215** for testing donor support **72**, which can include Fourier transform infrared spectroscopy (FTIR), that can provide moisture content information about donor support **72**. A set of parametric data **220** for process

feedback and a go/no-go mark 225 are derived from uncoated donor support tests 215. Go/no-go mark 225 can be e.g. a physical marking of good or bad sections, or can be computerized tracking of good or bad sections or parts.

Process flow 200 further includes a donor support deposition
5 system 230, in which donor support 72 receives an organic coating that is used several steps later in process flow 200 during radiation thermal transfer to deposit organic material to an OLED substrate 15. Some examples of donor support deposition system 230 have been described by Boroson et al in commonly assigned U.S. Patent 6,555,284, the contents of which are incorporated by
10 reference. Process flow 200 can further include one or more coated donor tests 235 for testing donor 60, which can include Fourier transform infrared spectroscopy (FTIR), that can provide moisture content information about donor support 72, and ellipsometry, that can determine layer thicknesses of organic material 70, from which a set of parametric data 240 for process feedback and a
15 go/no-go mark 245 are derived.

Process flow 200 further includes a radiation thermal transfer station 124 that transfers organic material 70 from the donor 60 to OLED substrate 15 using a radiation thermal transfer vacuum deposition process. Outputs from radiation thermal transfer station 124 include a post-RTT (post-radiation thermal
20 transfer) OLED substrate 260 and a used donor support 265. Post-RTT OLED substrate 260 is the article of manufacture that results from the radiation thermal transfer deposition of organic material to OLED substrate 15. Used donor support 265 is the remains of the coated donor 60 after the radiation thermal transfer process.

25 Process flow 200 can further include: one or more first in-situ tests 270 that are performed upon post-RTT OLED substrate 260 for testing organic layer 92 from which a first set of data 275 is obtained, and one or more second in-situ tests 280 that are performed upon used donor support 265 and from which a second set of data 285 is obtained. Process flow 200 can further include post-RTT
30 processing 290 that is performed upon post-RTT OLED substrate 260.

In operation, donor support 72 is manufactured offsite and supplied to process flow 200. Uncoated donor support tests 215 are conducted and result in parametric data 220, which can be used to determine which portions of donor support 72 are acceptable for further processing. The acceptable portions of donor support 72, and defective portions of donor support 72 can be noted in the memory of a software program (not shown) or can be used to provide a go/no-go mark 225 to donor support 72. Donor support 72 next enters donor support deposition system 230. Support 72 is coated to form donor 60. One or more coated donor tests 235 are subsequently performed on donor 60. The results of coated donor tests 235 are used to produce process control parametric data 240 and further can be used to provide a go/no-go mark 245 to donor 60. Coated donor tests 235 can include ellipsometry to determine the thicknesses of organic layer 92, material properties of the organic layer, dopant, and host concentrations, the presence of contaminants, etc. Using an area of donor 60 that is not going to be utilized for radiation thermal transfer enables coated donor tests 235 to include destructive testing methods such as photoluminescence or laser desorption mass spectroscopy. Defective portions of donor 60 as ascertained by parametric data 220 and 240 can be indexed and discarded later, enabling the translation of the defective portions of donor 60 to be sped up through the subsequent deposition processes. Alternately, if donor 60 is in the form of framed donor sheets, defective donors 60 can be discarded immediately.

Donor 60 next enters radiation thermal transfer station 124, in which the organic material 70 of donor 60 is transferred to OLED substrate 15. OLED substrate 15 can include previously deposited and tested layers, such as a hole-injecting layer and a hole-transporting layer as have been described above. Upon completion of the radiation thermal transfer processing, post-RTT OLED substrate 260 undergoes one or more first in-situ tests 270 from which first set of data 275 is derived. Concurrently, used donor support 265 undergoes one or more second in-situ tests 280 from which second set of data 285 is derived.

First in-situ tests 270 can occur within radiation thermal transfer station 124, e.g., by directing a laser beam through transparent portion 146 of

radiation thermal transfer station 124 and onto the layer deposited atop OLED substrate 15, or subsequent to radiation thermal transfer station 124 such as in measurement station 126, and can include destructive tests performed on test sites that will not be utilized in the final OLED display device, such as near the edge of a panel, or nondestructive tests performed anywhere on post-RTT OLED substrate 260.

Destructive first in-situ tests 270 that are performed on test sites can include photoluminescence to check the quality of the transferred material layer, Kelvin probe testing to measure the work function of the transferred material layer, atomic force microscopy (AFM) tests to determine the thickness and resolution of the transferred material layer, laser desorption mass spectroscopy to determine impurities, micro-Raman spectroscopy, X-ray fluorescence, or four point probe measurements.

Nondestructive first in-situ tests 270 can include diffracting a laser beam off of a set of lines that form a grating. In this specific embodiment, the grating is deposited along with the organic material atop OLED substrate 15 in a test area of OLED substrate 15 during the radiation thermal transfer process. The grating is illuminated to produce a diffraction pattern, the first order of which is analyzed to yield an indication of the transfer amount and the resolution quality of the transfer. In addition to the quality of the transferred material layer, analyses of the diffraction pattern provided by the grating further yields information regarding the performance of radiation thermal transfer station 124. Nondestructive first in-situ tests 270 can further include spectroscopic ellipsometry on the transferred material to ascertain transfer layer thickness and density.

Second in-situ tests 280 that are performed on used donor support 265 can include any of the aforementioned nondestructive or destructive tests due to the fact that the used donor support 265 is spent and no longer of use, and can include utilizing the ghost of a transferred diffraction grating that, similar to the nondestructive testing described above, can produce an interference pattern. In addition, comparisons can be made between organic material 70 atop donor 60 and the organic material that is transferred to post-RTT OLED substrate 260 by

comparing parametric data **240** and first set of data **275**. Such combination analysis provides valuable information about how both donor support deposition system **230** and radiation thermal transfer station **124** are behaving. For example, if parametric data **240** describes a suitable layer of organic material atop donor support **72** while first set of data **275** describes an unsuitable thermal transfer of the organic material to OLED substrate **15**, it is likely that the gap **84** provided between OLED substrate **15** and donor **60** during radiation thermal transfer is too large.

Upon undergoing first in-situ test **270**, post-RTT OLED substrate **260** advances to post-RTT processing **290**, which can specifically be chosen to be another thermal transfer of organic material. In one specific example, radiation thermal transfer is utilized to pattern each set of red, green, and blue pixels, in which case post-RTT OLED substrate **260** reenters process flow **200** illustrated in FIG. 5. In the case that no further radiation thermal transfer processing is necessary, post-RTT processing **290** can include more conventional deposition processes such as linear evaporation through a shadow mask or frame mask to deposit additional layers such as an electron-transporting layer or a cathode.

First in-situ tests **270** and second in-situ tests **280** can be performed upon each post-RTT OLED substrate **260** and each used donor support **265**, respectively, that are used during process flow **200** or, alternately, a fraction of post-RTT OLED substrates **260** and used donor supports **265** used during process flow **200** can be tested, e.g., every tenth post-RTT OLED substrate **260** and used donor support **265**. First set of data **275** and second set of data **285** can be further used to alter process parameters downstream to enable compensations to be made. This helps to increase yield and throughput of the radiation thermal transfer process via use of the collected information from first set of data **275** and second set of data **285**.

Turning now to FIG. 6, there is shown a block diagram of one embodiment of a method **300** of making an OLED device in accordance with this invention that corrects for potential defects identified in one processing station by adjusting a subsequent processing step. Method **300** includes the following steps:

In step 310, an OLED substrate 15 is processed by adding at least one organic layer as described herein. Conveniently, the organic layer(s) are light-emitting layers 35 that are coated by radiation thermal transfer from a donor 60 as described herein.

5 In step 320, selected in-situ tests are performed on OLED substrate 15 or donor 60, as described in reference to process flow 200 so as to measure one or more parameters associated with the organic layer (e.g. light-emitting layer 35). Such tests can include first in-situ test 270 and second in-situ test 280.

The selected in-situ tests are judiciously chosen from a set of either
10 nondestructive or destructive in-situ tests as appropriate, including but not limited to: nondestructive tests such as spectroscopic ellipsometry or diffraction of a laser beam off of a set of lines that form a grating, and destructive testing methods such as photoluminescence or laser desorption mass spectroscopy, Kelvin probe testing, atomic force microscopy, micro-Raman spectroscopy, X-ray fluorescence, or four
15 point probe measurements. The measurements produce a signal 325 representative of potential defects produced in an OLED device manufactured from OLED substrate 15. Donor 60 can be tested, e.g. second in-situ test 280 to determine if sufficient organic material 70 was transferred. Testing donor 60 can be performed instead of or in addition to testing OLED substrate 15.

20 In step 330, data (e.g. signal 325) is acquired from the selected in-situ tests and analyzed. Analyses of selected in-situ tests can be performed via an appropriate software program or, alternately, can be analyzed by a process engineer or technician. The analysis of data that occurs in step 330 provides both a set of parametric data (e.g. parametric data 240, data 275, or data 285) that is
25 stored for access by external process control, process monitoring, and lot binning functions (not shown) as well as information that is utilized for Step 340.

In decision step 340, the results of the data analyses performed in Step 330 are utilized to determine whether donor 60, OLED substrate 15, or any coatings thereon are of sufficient quality to continue through process flow 200. If
30 yes, Method 300 proceeds to Step 360. If no, Method 200 proceeds to Step 350.

In step 350, donor 60, OLED substrate 15, or any coatings thereon have been determined to have defective portions and OLED substrate 15 is withdrawn from process flow 200 or marked or noted as being of inferior quality. Method 300 can thus end.

5 In step 360, the results of the data analyses performed in Step 330 are utilized to feed information downstream in process flow 200 and can be utilized to compensate for any undesirable but manageable process variations.

In step 370, a subsequent processing station is adjusted in response to the data signal to change the formation of the subsequent organic layer to
10 compensate for undesirable but manageable potential defects identified in one processing station as a result of the data analysis performed in Step 330. For example, if it is determined that the thickness of the light-emitting layer 35 deposited atop OLED substrate 15 within radiation thermal transfer station 124 is 5 nanometers too thick, the subsequent deposition of the electron-transporting
15 layer 40 in coating station 130 can be reduced by 5 nanometers such that the voltage necessary to drive the OLED display device remains consistent. This helps to increase yield and throughput of the radiation thermal transfer process via use of the data analysis in Step 330. Method 300 then ends.

Turning now to FIG. 7, there is shown a block diagram of another
20 embodiment of a method 400 of making an OLED device in accordance with this invention that uses a donor to transfer organic material to a substrate. Method 400 includes the following steps:

In step 420, selected in situ tests are performed on donor 60 as described in reference to process flow 200 to determine if there is a defect and
25 identify the location of such defect in donor 60. Such tests can include uncoated donor support tests 215 and coated donor tests 235.

The selected in situ tests are judiciously chosen from a set of either nondestructive or destructive in situ tests as appropriate, including but not limited to: nondestructive tests such as spectroscopic ellipsometry or diffraction of a laser
30 beam off of a set of lines that form a grating, and destructive testing methods such as photoluminescence or laser desorption mass spectroscopy, Kelvin probe testing,

atomic force microscopy, micro-Raman spectroscopy, X-ray fluorescence, or four point probe measurements. The measurements produce a signal 425 representative of potential defects in donor 60 to determine if sufficient organic material 70 will be transferred.

5 In step 430, data (e.g. signal 425) is acquired from the selected in situ tests and analyzed. Analyses of selected in situ tests can be performed via an appropriate software program or, alternately, can be analyzed by a process engineer or technician. The analysis of data that occurs in step 430 provides both a set of parametric data (e.g. parametric data 220 and parametric data 240) that is
10 stored for access by external process control, process monitoring, and lot binning functions (not shown) as well as information that is utilized for Step 440.

 In decision step 440, the results of the data analyses performed in Step 430 are utilized to determine whether donor 60 or any coatings thereon are of sufficient quality to continue through process flow 200. If yes, Method 400
15 proceeds to Step 460. If no, Method 400 proceeds to Step 450.

 In step 450, donor 60 or any coatings thereon have been determined to have defective portions and donor 60 is withdrawn from process flow 200 or marked or noted as being of inferior quality. Method 400 thus ends.

 Alternatively, donor 60 can be reworked in a further step (not
20 shown) to correct for the substandard coating of organic material 70.

 In step 460, an OLED substrate is processed by using radiation to transfer organic material 70 from donor 60 to OLED substrate 15. Step 460 can be adjusted to compensate for undesirable but manageable defective portions of donor 92 that are discovered as a result of the data analysis performed in Step 430.
25 For example, if only portions of donor 60 are defective, organic material 70 can be transferred from acceptable portions of donor 60 to OLED substrate 15 to form an organic layer by excluding the identified defective portions of donor 60. This is particularly convenient when donor 60 is in the form of a continuous web.

PARTS LIST

10	OLED device
15	substrate
20	anode
25	hole-injecting layer
30	hole-transporting layer
35	light-emitting layer
40	electron-transporting layer
50	cathode
60	donor
62	laser light beam
63	non-transfer surface
65	transfer surface
70	organic material
72	support
74	radiation-absorbing layer
80	thin-film transistor
82	raised surface portion
84	gap
86	receiving surface
90	heat
92	organic layer
100	controlled environment coater
110	unitary housing
112	controlled environment source
114	load lock
116	load lock
120	coating station

PARTS LIST (con't)

122	robot
124	radiation thermal transfer station
126	measurement station
128	robot
130	coating station
131	grasping means
134	coating apparatus
138	laser
140	measurement apparatus
146	transparent portion
148	coating apparatus
150	computer
152	data input/output
154	data input/output
156	data input/output
158	data input/output
200	process flow
215	uncoated donor support tests
220	parametric data
225	go/no-go mark
230	donor support deposition system
235	coated donor tests
240	parametric data
245	go/no-go mark
260	post-RTT OLED substrate
265	used donor support
270	in-situ test

PARTS LIST (con't)

275	data
280	in-situ test
285	data
290	post-RTT processing
300	method
310	block
320	block
325	signal
330	block
340	decision block
350	block
360	block
370	block
400	method
420	block
425	signal
430	block
440	decision block
450	block
460	block

WHAT IS CLAIMED IS:

1. A method of making an OLED device that corrects for potential defect(s) identified in one processing station by adjusting a subsequent processing station, comprising:
 - 5 a) processing an OLED substrate by adding at least one organic layer and measuring in-situ one or more parameters associated with such organic layer to produce a signal representative of potential defect(s) in a produced OLED device; and
 - b) adjusting in a subsequent processing station in response to
10 the signal to change the formation of a subsequent organic layer added to the OLED device to compensate for the potential defect(s).
2. A method of making an OLED device that corrects for potential defect(s) identified in one processing station by adjusting a subsequent processing station, comprising:
 - 15 a) using radiation to transfer organic material from a donor to an OLED substrate to form an organic layer and measuring in-situ one or more parameters associated with such organic layer to produce a signal representative of potential defect(s) in a produced OLED device; and
 - b) adjusting a subsequent processing station in response to the
20 signal to change the formation of a subsequent organic layer added to the OLED substrate to compensate for the potential defect(s).
3. The method of claim 1 wherein element a) includes using ellipsometry to determine the thickness of the organic layer and produce a signal representative of such thickness and wherein element b) adjusts the thickness of
25 the subsequent organic layer.

4. The method of claim 1 wherein spectroscopic ellipsometry, diffraction of a laser beam, photoluminescence, laser desorption mass spectroscopy, Kelvin probe testing, atomic force microscopy, micro-Raman spectroscopy, X-ray fluorescence, or four point probe measurements are used to
5 determine the thickness of the organic layer and produce a signal representative of such thickness and wherein element b) adjusts the thickness of the subsequent organic layer.

5. In a method of making an OLED device that corrects for potential defect(s) identified in one processing station by adjusting a subsequent
10 processing station or rejects the device, comprising:
a) using radiation to transfer organic material from a donor to an OLED substrate to form an organic layer and measuring in-situ one or more parameters associated with such organic layer to produce a signal representative of potential defect(s) in a produced OLED device; and
15 b) adjusting a subsequent processing station in response to the signal to change the formation of a subsequent organic layer added to the OLED substrate to compensate for the potential defect(s) or rejecting the device.

6. The method of claim 5 wherein the rejected device is reworked to correct for identified defect(s).

20 7. A method of making an OLED device that corrects for potential defect(s) identified in one processing station by adjusting a subsequent processing station or rejecting or reworking the device, comprising:
a) using radiation to transfer organic material from a donor to an OLED substrate to form an organic layer; and
25 b) testing in-situ the donor or the organic layer on the substrate or both to determine if sufficient organic material was or will be transferred and, if insufficient material was or will be transferred, rejecting or reworking the device to correct for the incomplete organic material transfer.

8. The method of claim 7 wherein the testing of the donor includes spectroscopic ellipsometry.
9. The method of claim 7 wherein the reworking the device includes radiation thermal transfer of an organic layer to the defective locations on
5 the device using an additional donor.
10. The method of claim 7 wherein the testing of the substrate includes spectroscopic ellipsometry.
11. A method of making an OLED device that uses a donor to transfer organic material to a substrate, comprising:
- 10 a) testing in-situ the donor to determine if there is a defect and identifying the location of such defect in the donor; and
- b) using radiation to transfer organic material from acceptable portions of the donor to an OLED substrate by excluding the identified defective portions of the donor to form an organic layer.
- 15 12. The method of claim 11 further including:
- c) testing in-situ the donor or the organic layer on the substrate or both to determine if sufficient organic material was or will be transferred and, if insufficient material was or will be transferred, rejecting or reworking the device to correct for the incomplete organic material transfer.

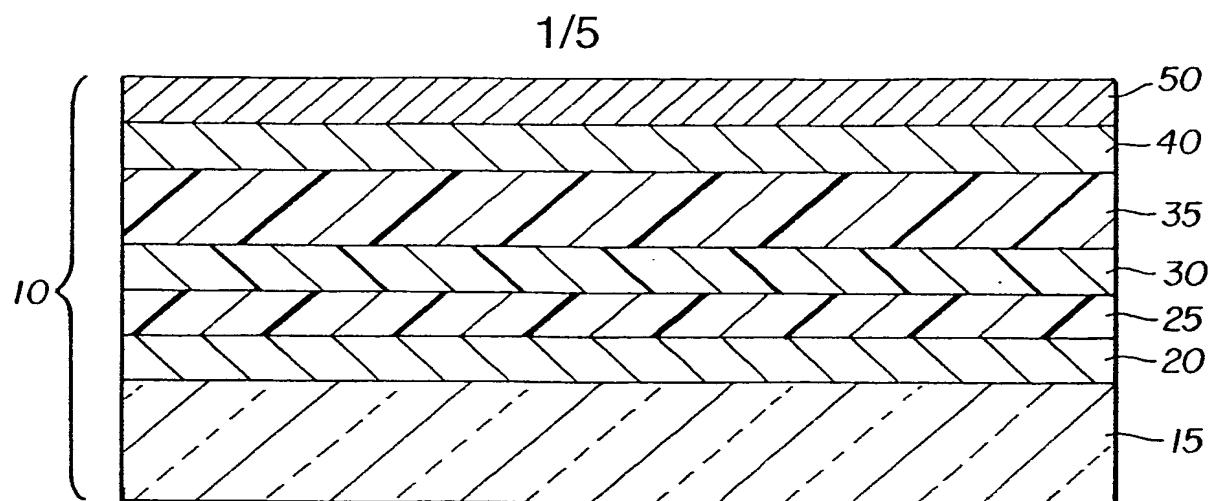


FIG. 1

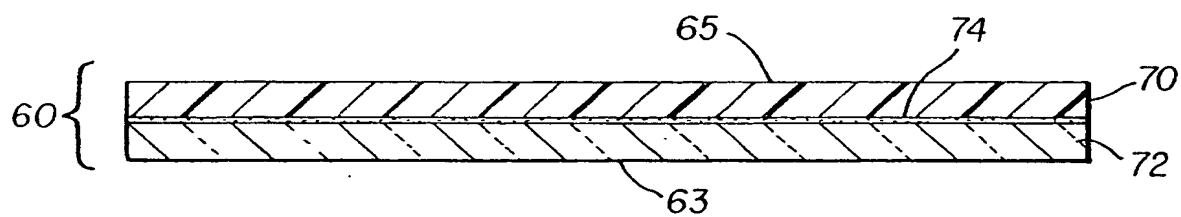


FIG. 2

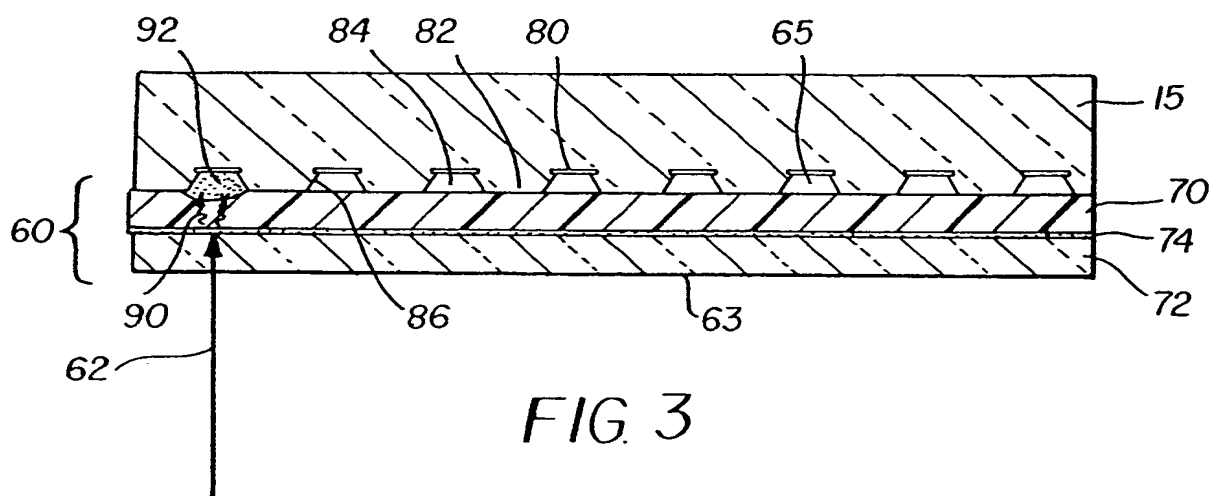
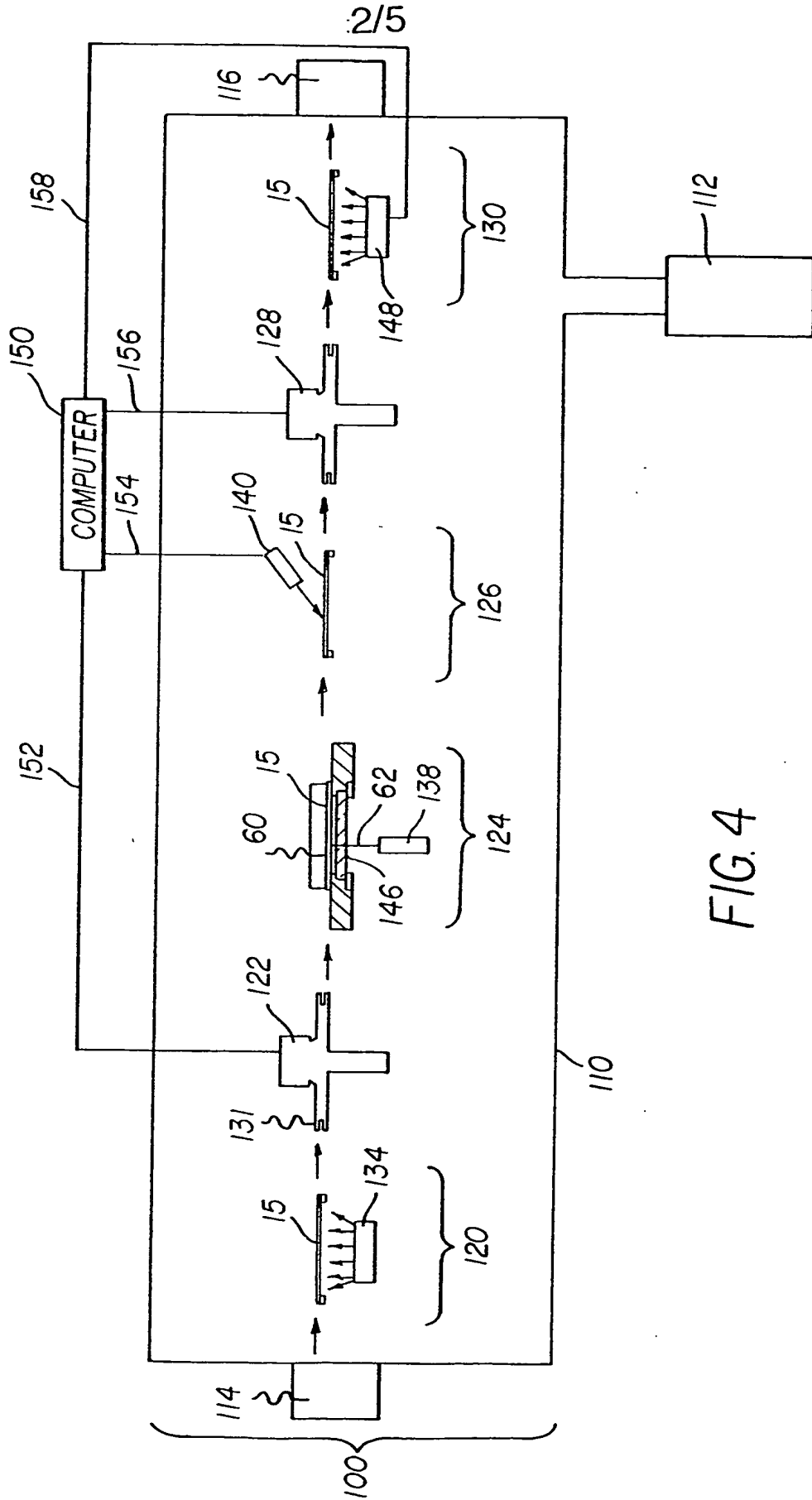


FIG. 3



3/5

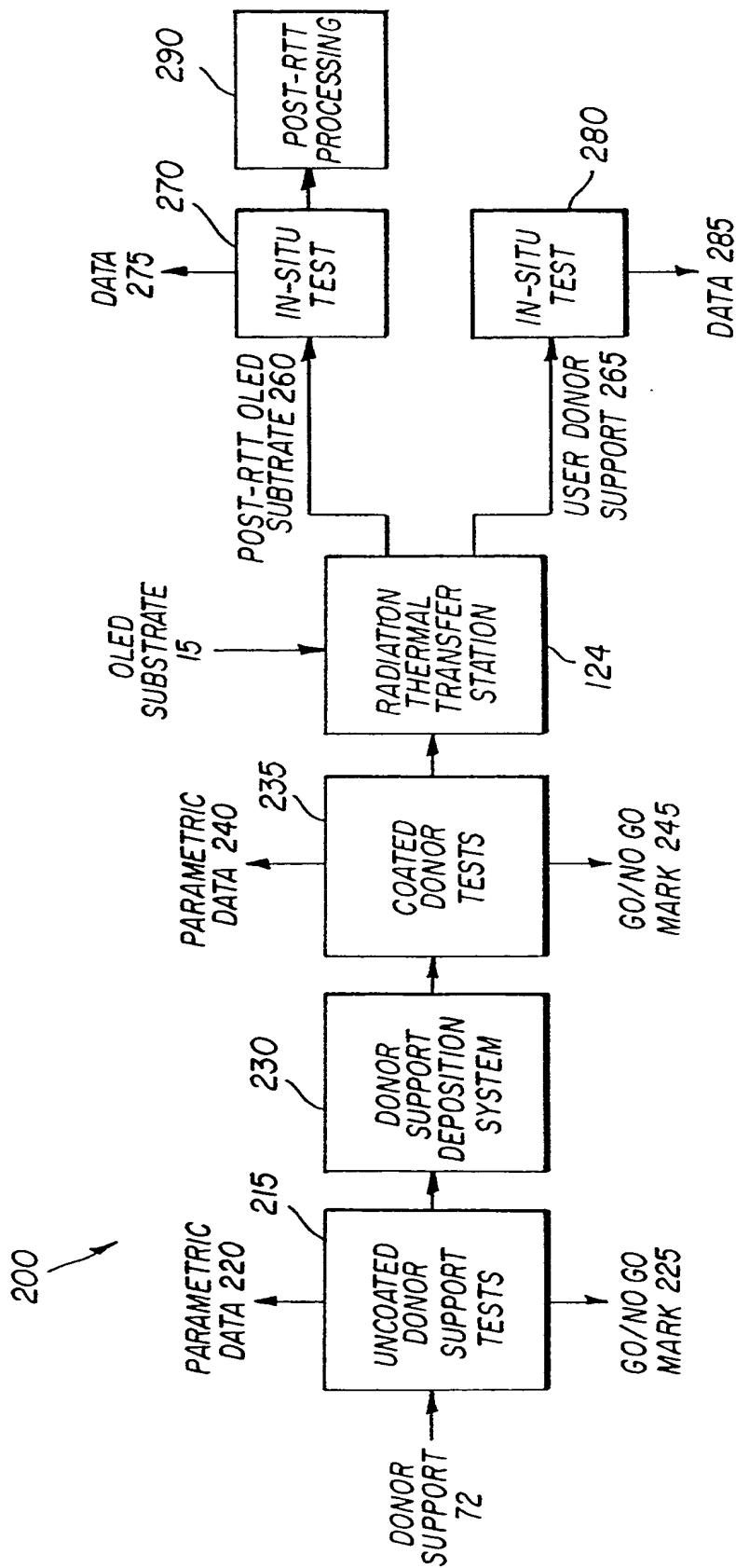


FIG. 5

4/5

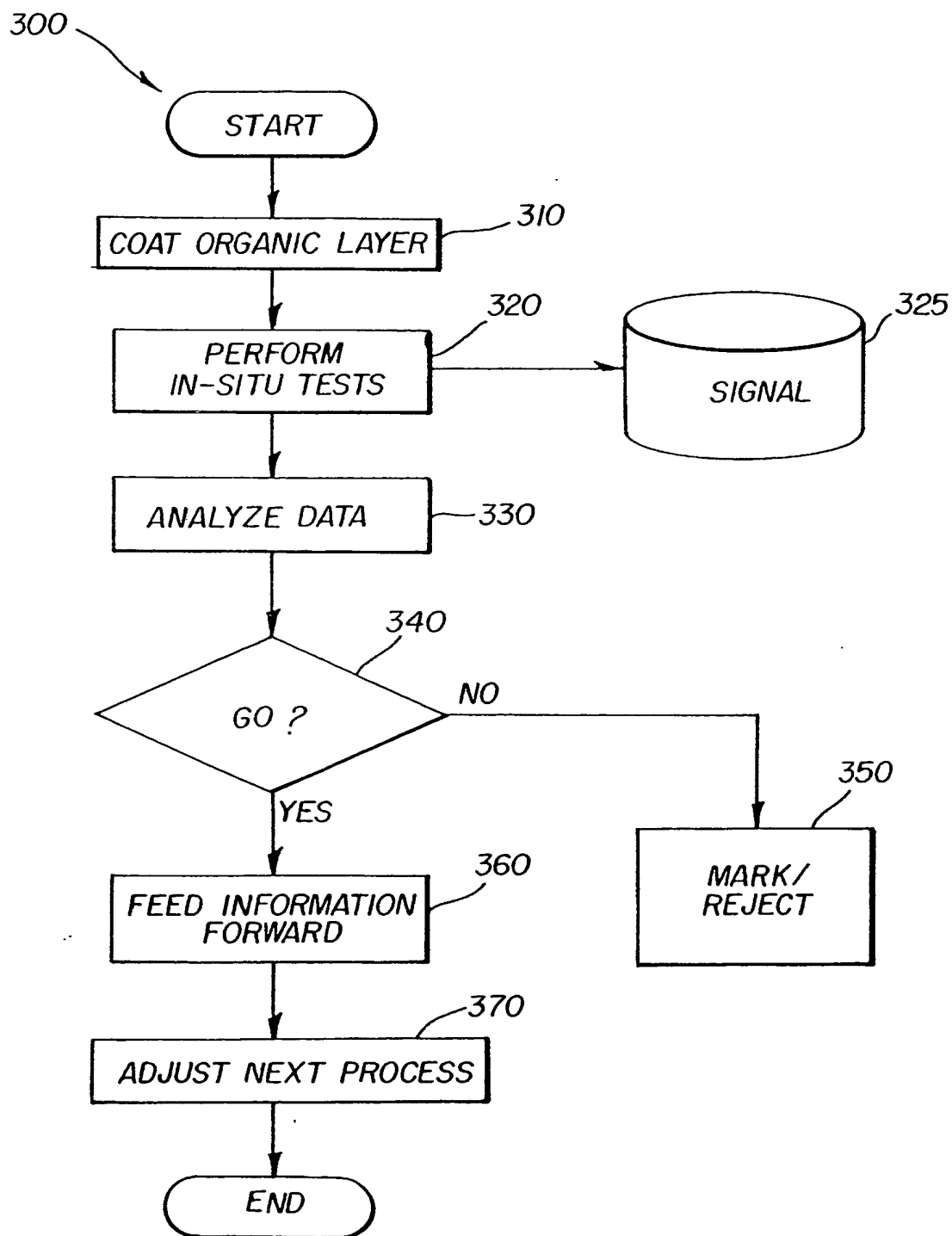


FIG. 6

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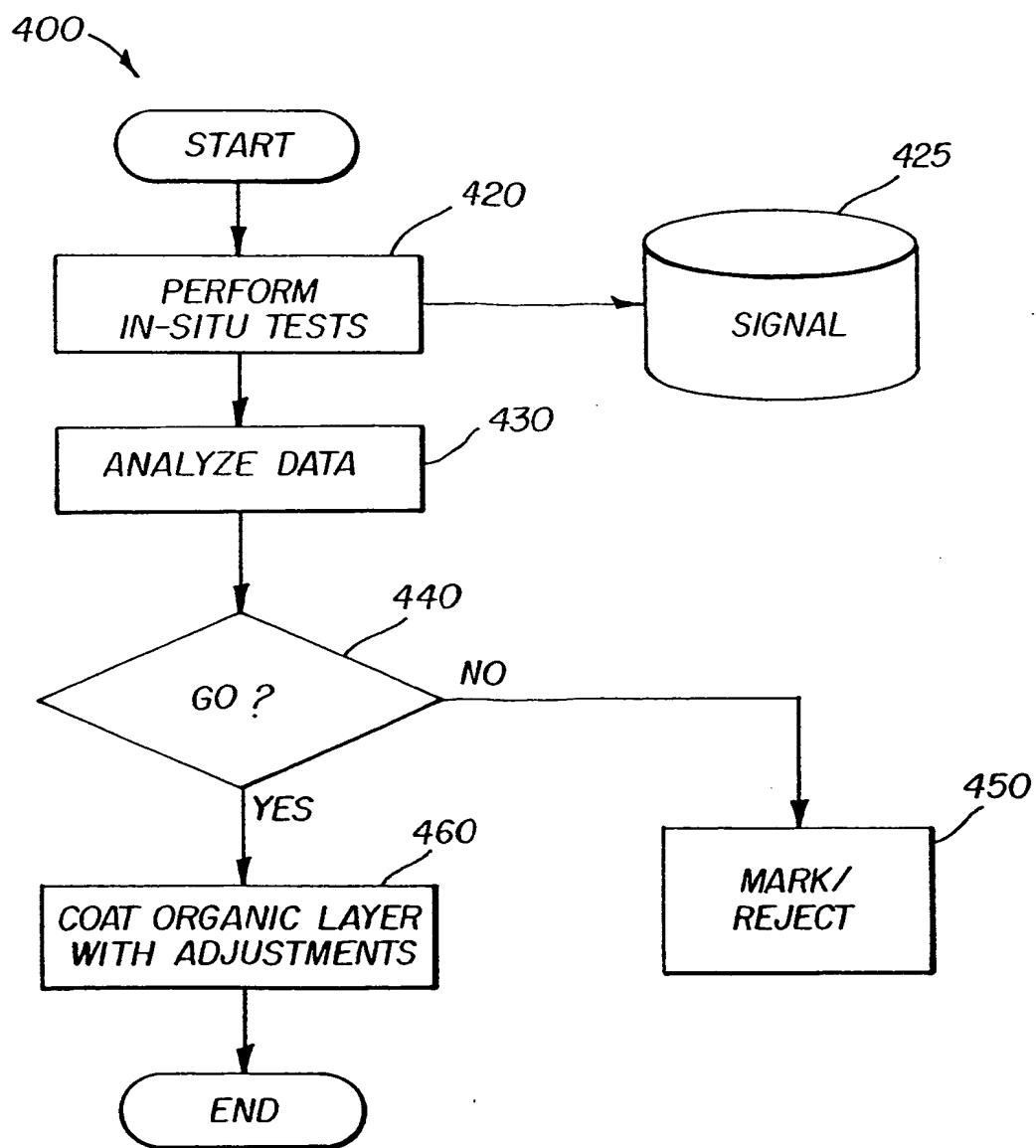


FIG. 7